RESEARCH PROPOSAL

"A Study on Fuzzy Multi- Objective Solid Transportation Problem"

A synopsis submitted to

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1. Introduction

Operations Research may be described as the application of scientific methods to problems arising from operations involving integrated systems of people, machine and material. It has been applied to several decision-making problems in the last five decades. Operations Research methods are very often used in Management science, Economic, Mathematics, Statistics and Industrial Engineering. The main aim of the Operations Research is to seek the best course of action of a decision-making problem under certain constraints. Ever since the introduction of Simplex method by Dantzig in 1947 to solve the linear programming problem, it has been proven to be one of the most effective tools in Operations Research. Its success stems from its flexibility in describing multitudes of real-life situations in the following areas: Military, Industry, Agriculture, Transportation, Economics, Health systems, and even behavioral and Social Sciences. One of the most fruitful applications of linear programming techniques has been the formulation and solution of the Transportation Problem (TP) as a linear problem. TP is one of the optimization problems most widely used by private and public sectors. The present standard form of the transportation model was formulated along with a solution procedure by Hitchcock [9]. He considered the problem of minimizing the cost of distribution of product from several factories to a number of customers. Koopmans [13] took the leading role in bringing to the attention of economists, the potentialities of the linear programming models. The rapid development of the economic theory of such models was due to the insight gained by the researchers during the world war-II with a special class of linear programming models called transportation model. The problem is called transportation problem because it involves the 2 transportations of goods from several sources to a number of destinations. Dantzig [5, 6] formulated the transportation problem as a special class of linear programming problem and then developed a special form of simplex technique, taking advantage of the special nature of the coefficient matrix and involving hundreds of equations in thousands of unknown variables. Transportation problem can be broadly classified into two major categories, namely, single-objective and multi-objective transportation problem.

The transportation problem which takes into account three types of constraints, namely, source, destination, and conveyance constraints instead of only source and destination constraints. This generalized problem is called the Solid Transportation Problem (STP). STP having three items as supply, demand, and conveyance is one of the most important implemented to several real-life problems. If there are multiple non-commensurable and conflicting objectives, then the corresponding problem is called the multi-objective Solid Transportation Problem (MOSTP). The MOSTP is type of vector minimization (or maximization) problem with three parameters: source, destination, and mode of transport. It may have fractional objective functions in real-life applications to maximize the profitability ratio like profit/cost or profit/time. In today's business environment, competition is increasing day by day and each organization aims to find better ways to deliver values to the customers in a cost-effective manner within the specified time and fulfill their demands. For this they think of different ideas. One of the ideas can be using different type of transportation modes to save time and money.

STP is an extension of the classical transportation problem. If more than one objective is to be optimized in an STP, then the problem is called MOSTP. Also because of imprecise data, information uncertainty arises in a STP. The STP is the process of distributing certain products from its manufacturing points (sources) to the different demand points (destinations), using different conveyances and keeping in mind the factor of different transportation capacities and transportation costs, fixed charge costs, etc. so that total transportation cost is minimum. The multi objective transportation problems are reduced to single objective transportation problem using weighted Tchebycheff method.

In applications, the STP generally requires considering multiple objectives such as cost minimization, time minimization, security level maximization, etc. In this way, a MOSTP arises.

- **Transportation Problem:**

Let us consider that there are m sources and n destinations. Let x_{ij}be the amount to be shipped from source$i$to destination j, $1 \leq i \leq m, 1 \leq j \leq n$. x_{ij}will be an integer greater than, or equal to, zero. Also let $a_i$be the amount of supply at source $i = 1, \ldots, m$and $b_j$the demand at destination$j = 1, \ldots, n$. The unit Transportation cost from source i, to destination j is$c_{ij}, 1 \leq i \leq m, 1 \leq j \leq n$. The linear programming from with the inequality constrain transportation problem in the case I therefore

Case I: [1]

$$Minimize\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}\, x_{ij} \qquad (1)$$

subject to

$$\sum_{i=1}^{m} x_{ij} \geq b_j \quad j = 1,2,3, \ldots, n \qquad (2)$$

and

$$\sum_{j=1}^{n} x_{ij} \leq a_j i = 1,2,3, \ldots, m \qquad (3)$$

where $x_{ij} \geq 0\ and\ x_{ij}$ integer.

For the model to be feasible must have the total supply is at least equal to the total demand

$$\sum_{i=1}^{m} a_i \geq \sum_{j=1}^{n} b_j \qquad (4)$$

Case II: Single Objective Transportation problem with equality constraints [1]

A transportation problem can be represented as a single objective transportation problem

$$MinZ = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \qquad (5)$$

$$Subject\ to \quad \sum_{i=1}^{m} x_{ij} = a_i, i = 1,2, \ldots, m \qquad (6)$$

$$\sum_{i=1}^{m} x_{ij} = b_j, j = 1,2, \ldots, n \qquad (7)$$

$$x_{ij} > 0, i = 1,2, \ldots, m\ , j = 1,2, \ldots, n$$

In real world transportation problem, input data or related parameters are often imprecise / fuzzy owing to incomplete or unobtainable information. A transportation problem can be represented as a multi objective transportation problem

$$MinZ_k = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}\,, \qquad k = 1,2,\dots\dots\dots k \quad (8)$$

$$Subject\ to \sum_{i=1}^{m} x_{ij} = a_i, i = 1,2,\dots,m \quad (9)$$

$$\sum_{i=1}^{m} x_{ij} = b_j, j = 1,2,\dots,n \quad (10)$$

$$x_{ij} \geq 0, i = 1,2,\dots\dots\dots,m\,, j = 1,2,\dots\dots\dots\dots,n$$

The subscript on Z_k and superscript on c_{ij}^k denote the k-th penalty criterion, $a_i > 0\ for\ all\ i, b_j > 0\ for\ all\ j, c_{ij}^k > 0\ for\ all\ (i,j), and\ \sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$ (balanced condition).

- **Solid Transportation Problem (STP) [10]**

Consider m origins, which contain various amounts of a commodity that has to be shipped to n destinations by means of $\boldsymbol{l}$ conveyances. Let $\boldsymbol{a_i}$ be the amount of the commodity available at the origin $\boldsymbol{i}$; $\boldsymbol{b_j}$ be the amount required at the destination $\boldsymbol{j}$ and $\boldsymbol{e_k}$ be the amount transported by conveyance $\boldsymbol{k}$. Let $\boldsymbol{c_{ijk}}$ be the cost of shipping a unit amount from the origin $\boldsymbol{i}$ to the destination $\boldsymbol{j}$ by means of the conveyance $\boldsymbol{k}$. Let $\boldsymbol{x_{ijk}}$ be the amount shipped from the origin $\boldsymbol{i}$ to the destination $\boldsymbol{j}$ by means of the $\boldsymbol{k^{th}}$ conveyance. In the STP aim is to determine the transportation schedule to minimize the transportation cost satisfying supply, demand and conveyance constraints. Now, the linear programming model of the above STP is given below:

$$\text{(P1) Minimize z} = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{l} c_{ijk}\,x_{ijk} \quad (11)$$

subject to the constraints,

$$\sum_{j=1}^{n}\sum_{k=1}^{l} x_{ijk} = a_i, i = 1,2,\dots m \quad (12)$$

$$\sum_{i=1}^{m}\sum_{k=1}^{l} x_{ijk} = b_j\,, j = 1,2,\dots n \quad (13)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ijk} = e_k, k = 1,2,\dots l \quad (14)$$

$x_{ijk} \geq 0$, for all i,j and k (15)

Any set of non-negative allocations to the problem (P1) which satisfies the equations (12), (13), (14) and (15) is called a feasible solution to the problem (P1).A feasible solution to the problem (P1) which minimizes the total shipping cost $\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{l} c_{ijk}\,x_{ijk}$ is called an optimal solution to the problem (P1). If one of basic variable in the optimal solution of the problem (P1) is zero, that is, the number of non-zero basic variables is less than $m + n + l - 2$, then the problem (P1) is called degenerate.

If

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j = \sum_{k=1}^{l} e_k \quad (16)$$

The problem (P1) is said to be balanced. Otherwise, it is called unbalanced. The balanced condition is the necessary and sufficient condition for the existence of a feasible solution to the problem (P1). If$l = 1$, the number of conveyances is only one, the problem (P1) reduces to a classical transportation problem. [18]

- **Multi Objective Solid Transportation Problem(MOSTP)[1]**

The MOSTP is formulated as:

$$Minimize\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{K} c_{ijk}\, x_{ijk}\, max_{ijk}\{t_{ijk}, x_{ijk} > 0\} \qquad (17)$$

subject to the constraint's Eq.(12-15)

Where,

$t_{ijk}$is the time of transporting k^{th}type of commodity from i^{th} source to j^{th}destination. $max_{ijk}\{t_{ijk}, x_{ijk} > 0\}$is the maximum time corresponding to the non-zero allocation x_{ijk}

The time $t_{ijk}$is independent of the quantity transported of any type of commodity transported between any source-destination pair. The objectives of the problem are conflicting in nature as improvement in one compromise the optimality of the other, thereby leading to the identification of Pareto optimal solutions.

- **Fuzzy MOSTP Model [1]**

Consider that m origins (or sources), n destinations and K conveyances. Let $a_i$be the amount of homogeneous product at i^{th} origin which is transported to n destinations to satisfy the demand for b, units of the product there. Let $e_k$be the units of this product which can be carried by K different modes of transportation called conveyances. We denote the fuzzy numbers (coefficients) of q^{th} objective as in $\tilde{c}_{ijk}^{q}, (q = 1,2,\dots,Q)$ which are associated with transportation of a unit of the product from source i to destination j by means of the conveyance k. The fuzzy number could represent transportation cost, delivery time, quantity of goods delivered, under-used capacity, and so on. They may be uncertain due to some environmental impacts. Therefore, it is necessary to treat these coefficients as fuzzy numbers.

A decision variable x_{ijk}represents the unknown quantity to be transported from origin i to destination j by means of the conveyance k. The MOSTP with fuzzy numbers can be formulated as follows:

$$\min \tilde{z}_q\,(x) = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{K} \tilde{c}_{ijk}^{q} x_{ijk}\,, \qquad q = 1,2,\dots,Q \qquad (18)$$

$$s.t. \sum_{j=1}^{n}\sum_{k=1}^{K} x_{ijk} = a_i, \qquad i = 1,2,\dots,m \qquad (19)$$

$$\sum_{i=1}^{m}\sum_{k=1}^{K} x_{ijk} = b_j\,, \qquad j = 1,2,\dots,n \qquad (20)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ijk} = e_k\,, \qquad k = 1,2,\dots,K \qquad (21)$$

$$x_{ijk} \geq 0, \qquad \forall\, i,j,k.$$

Where,

$$a_i \geq 0, \qquad \forall\, i;\ b_j \geq 0, \forall\, j;\ e_k \geq 0, \forall\, k;\ \tilde{c}_{ijk}^{q} \geq 0, \forall\, i,j,k,q\ and$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j = \sum_{k=1}^{K} e_k\ (balanced\ condition) \qquad (22)$$

The balanced condition is both a necessary and sufficient condition for the existence of a feasible solution to the problems.

2. Review of Literature and Development in the subject.

Li et al.[15] present an implementation of genetic algorithm to solve the fuzzy MOSTP in which the fuzzy numbers are used in the objective functions. They use ranked fuzzy numbers with integral values to calculate evaluation and selection. The proposed algorithm is incorporated with problem-specific knowledge and conductive to find out the set of non-dominated points in the criteria space based on decision maker degree of optimism. And the method is combined with the global criterion method to provide the best compromise solution for decision maker. Roy et al.[21] proposed MOTP, all the parameters of TP are considered as intuitionistic fuzzy numbers (IFNs) due to fluctuation of market scenario and $(\propto, \beta)$cut to convert IF transportation cost into an interval, and demand and supply into inequalities. Values of a and b are chosen by the decision maker according to his/her choice. Also deduct a crisp mathematical model with interval-valued objective function, from the proposed intuitionstic FMOTP. Two approaches, namely IFP and GP, are considered to solve the interval valued MOTP and the obtained solutions are also solutions of the primary IFMOTP at $(\propto, \beta)$ cut level. Different values of a and b provide different solutions and the decision maker has a freedom to choose a better solution.

Gakhar et al.[8] worked as the total time STP is considered in which the objective is to minimize the time of active transportation routes. Ammar et al. [1] study a FMOSTP, with fuzzy coefficient, fuzzy supply values of the supplies, with fuzzy demand values of the receivers and fuzzy conveyances quantities and also introduced the concepts of fuzzy efficient and parametric efficient solutions. An algorithm to determine the stability set corresponding to the one parametric efficient of parametric MOSTP is presented. Chevli et al.[3] focus on solution of fixed charge STP by Grey Situation Decision (GSD) making theory with membership function. Kavitha and Pandian [18] proposed a new method namely, zero-point bound method to improve the sensitivity analysis of supply, demand and conveyance parameters in STP. Result of their study showed that the basis to the STP remains optimal when the supply, demand and conveyance vary between the limits. Ammar et al. [1] study vector fuzzy transportation problem (VFTP) with fuzzy supply values of the suppliers and with fuzzy demand values of the receivers. They have given characterizing of the active solution set of this problem. By use the concept of α-efficiency they deduce the corresponding usual problem α VTP. For the triangular fuzzy numbers, the relations between the solutions of the α-VTP and its dual problem are presented. They introduce an algorithm to determine the stability set corresponding to one α-efficient solution of α-VTP.

Dalman [4] a fuzzy programming approach based on the theory of interval numbers is employed to solve the interval MOSTP. In the first step, the considered interval MOSTP is converted into a crisp MOSTP. Then the best and worst solutions of each objective function are determined. In next step, the method based on fuzzy programming tries to reach the better compromise solution which simultaneously satisfied different objectives. Finally, the results of recommended fuzzy approach are compared with the existing fuzzy programming approach based on the theory of interval numbers is employed to solve the MOSTP. In the first step, the considered interval MOSTP is converted into a crisp MOSTP. Then the best and worst solutions of each objective function are determined. In next step, the method based on fuzzy programming tries to reach the better compromise solution which simultaneously satisfied different objectives. Finally, the results of recommended fuzzy approach are compared with the existing fuzzy approach. Peng et al. [19] analyzed a transportation problem with interval-valued trapezoidal fuzzy values for the transportation costs, demands and supplies. They named such TP as fully interval-valued fuzzy TP and proposed a novel solution approach to obtain the interval-valued fuzzy optimal transportation cost. Amreen [2] proposed method combines normal distribution with the root mean square technique to transform transportation costs into probability-based values and calculate penalties for rows and columns, aiming to improve results. It is adaptable to both balanced and unbalanced transportation problems, often producing optimal or near-optimal solutions. They evaluated initial basic feasible solution for optimality using the Stepping Stone approach. However, their study is

limited to the use of the Normal Distribution's Cumulative Distribution Function (CDF), not the Probability Density Function (PDF). Shivani and Rani [22] investigated a multi-objective green transportation problem, focused on carbon emissions as a major pollution source. It compares the impact of two driving styles - defensive (right) and aggressive (wrong) - on carbon emissions and transportation costs. To address uncertainties in real-world data, interval-valued triangular intuitionistic fuzzy numbers (IVTIFNs) are used. Their model is converted into a crisp form and solved using three techniques: weighted Tchebycheff metrics programming, IVIF programming, and fuzzy TOPSIS. Their results show that the defensive driving style leads to better environmental and economic outcomes. Kacher and Singh [11] presented a two-step generalized parametric approach for solving fuzzy parameter-based FMOTPs, which involved uncertain or imprecise data. Their approach provides decision-makers with multiple optimal solutions for varying values of the precision parameter μ. The methodology involves partitioning fuzzy data into split levels and solving the transformed problems using fuzzy programming techniques. The grey relational analysis (GRA) is applied to identify the best compromise solution at each split level, with the preferred solution selected based on its minimal Euclidean distance to the ideal solution. Their method demonstrated through three numerical problems and compared to existing methods, highlighting its practical effectiveness in transportation decision-making.

3. Objectives of the Research:

Some of the major aims and objectives of the research study are:

- To study Single-objective, bi-objective, multi-objective transportation problem.
- To study Single-objective, bi-objective, multi-objective solid transportation problem.
- To study Fuzzy multi-objective solid transportation problem.
- Apply LINDO or any Scientific Tool to solve the fuzzy multi-objective solid transportation problem.
- Try to develop new algorithms to optimize Fuzzy multi-objective solid transportation problem.
- Try to investigate some properties of the solutions existence, uniqueness and other of fuzzy multi-objective solid transportation problem.
- Try to apply the solid transportation problem analysis to the various fields of day-to-day life, business and technology.

During the period of research many new objectives may be developed which will be beneficial for the society.

4. Methodology:

- Collection of relevant literature from good libraries in India and abroad.
- Solution of fuzzy multi-objective solid transportation problem by regular methods.
- Understanding regular MOSTP and FMOSTP problem.
- Use of scientific tools available for the solution FMOSTP problem.
- Consultations with expertise on topics relevant to proposed work.

5. Importance of Study / Society application:

In this proposed work, main focus is to study and apply the optimization techniques for the determination of the solution of Fuzzy multi-objective solid transportation problem. In real life we may face many complex equations while constructing the Solid Transportation Problem and fuzzy linear programming problem. Use of other scientific tool will provide an easy access for such complex equation and can generate approximate solutions.

- **National and International Status**

Kara and Köçken [12,17] proposed a fuzzy approach that combines the usage of linear programming and the golden section algorithm with linear and exponential membership functions and a strongly efficient solution is obtained. Kundu et al. [14] proposed Fuzzy programming technique and global criterion method are applied to derive optimal compromise solutions of multi-objectives. A defuzzification method based on fuzzy linear programming is applied for fuzzy supplies, demands and conveyance capacities, including the condition that both total supply and conveyance capacity must not fall below the total demand. Lohgaonkar et al.[16] present a fuzzy multi-objective multi-index transportation problem and developed multi-objective multi-index fuzzy programming model.

Jana et al, [10] proposed model is formed with fuzzy imprecise nature. Such an interesting model is optimized through two different fuzzy programming techniques and fractional programming methods, using LINGO-14.0 tools followed by the generalized gradient method. MOSTP is known as a special class of vector-minimization (or maximization) problems and has three parameters: source, destination, and conveyance. The objectives such as transportation cost, transportation time, transportation safety level, and objectives in terms of environmental and social issues are generally in conflict with each other. They present a fuzzy approach to bring these conflicting objectives together as high as possible. Instead of using the linear membership function, which is frequently used in the literature for ease of use, they use the hyperbolic membership function in our approach. Also, while most of the papers in the literature deal with the standard equality constrained form of MOSTP, the mixed constrained form is addressed. [15]

The problem of minimizing total cost of transportation problem is one of many well-structured problems in operations research that has been studied in detail. The transportation problem is one of the subclass linear programming problems which are similar in that they all require a linear function of a set of variables is optimized while the variables themselves satisfy a number of linear constraints for which simple and practical computational procedures have been developed. The time minimization transportation problem is one in which a time is associated with each shipping route and the objective is to minimize the maximum time to transport all supply to the destinations. The problem becomes more complex in case of STP. Their focus is to minimize the time of active transportation routes.[8]

The STP arises when bounds are given on three item properties. Usually, these properties are supply, demand, and type of product or mode of transport (conveyance) and investigate the efficient solutions and stability of MOSTP with fuzzy coefficient and/or fuzzy supply quantities and/or fuzzy demands quantities and /or fuzzy conveyances quantities. The concept of fuzzy efficient was introduced in which theα ordinary efficient solution is extended based on the level of fuzzy numbers. A necessary and sufficient condition for such a solution is established. The basic notions as the solvability set and the stability set of the first kind are defined and characterized. The parametric analysis is used to characterize the parametric optimal solutions to the auxiliary problems. An algorithm and flowchart for the determination of the stability set is proposed. Finally, a numerical example is given.[1]

The fixed charge STP under uncertainty is investigated. Nowadays finding an efficient solution for transportation problem is one of the main issues for organizations and industries. According to the real world, it is assumed that the products are transported with fixed charge STP. Besides, the fuzzy values are used conferring to the value of the parameter in the real world. They focus on solution of fixed charge STP transportation problem by Grey Situation Decision (GSD) making theory with membership function.[3]

Sensitivity analysis (SA) of supply, demand and conveyance parameters of STP is presented. A new solution method namely, zero-point bound method is proposed to determine the ranges of supply, demand and conveyance parameters in STP such that its optimal basis is invariant. The procedure and efficiency of this approach are shown with numerical example. The SA of STP by the zero-point bound method can support the decision makers to determine what level of accuracy is essential for a parameter to make the model sufficiently useful and valid when

they are handling distribution problem having crisp parameters.[12]

A transportation problem involving multiple objectives, multiple products, and three constraints, namely, source, destination, and conveyance, is called the multi-objective multi-item STP (MOMISTP) [20]. Recently, Kundu et al.[14] (2013) proposed a method to solve an unbalanced MOMISTP. They suggest a method, which first converts an unbalanced problem to a balanced one. In one case of an example, while the method proposed by Kundu et al.[14] concludes infeasibility, their's method gives a feasible solution.

Das [7] made an investigation on interval STP.A capacitated, interval valued STP with interval nature of resources, demands, capacity of conveyance and costs. Here transportation cost inversely varies with the quantity-to be transported from plants to warehouses in addition to a fixed per unit cost and a small vehicle cost. They develop this work under unit transportation cost, resources, demands, conveyances capacities etc. as interval numbers. To erect this manuscript, an additional constraint is imposed on the total budget at each goal. They employ two interval approaches as Hu and Wang's and Mahato and Bhunia's approaches. The interval transportation model is converted into its crisp equivalent by using Weighted Tchebycheff method and also the model is illustrated with numerical example using the LINGO.13 optimization software.

- **Significance of the study**

In real world transportation planning, decision problems, input data and related parameters, such as available supply and future demand, are often imprecise because some information may be incomplete or unobtainable. In this case the scientific tools will help us to solve such problems with complex equations to minimize the total cost of transportation along with the total delivery time with reference to constraints of available supply and future demand.

6. Proposed work Plan/ Formulation and Structure of Study:

Tentative Year-wise Plan of work and targets to be achieved

- **First Year**
  1. To collect and study of review of literature of fuzzy multi-objective solid transportation problem.
  2. To find the solution of the fuzzy MOSTP and introduction of fuzzy multi-objective solid transportation problem.
- **Second Year**
  1. To apply the scientific tool for the transportation and fuzzy transportation problem.
  2. Try to develop new model for optimizing fuzzy multi-objective solid transportation problem.
  3. To solve fuzzy multi-objective solid transportation problem using different methods and to compare the results.
- **Third Year**
  1. The publication of the findings of the research.
  2. Publication of papers in various national and international journals & conferences.
  3. Thesis writing.

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